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Title: Design of the Coherent CAPTAIN Mills (CCM) Roof Shielding Package

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Los Alamos
NATIONAL LABORATORY

Design of the Coherent CAPTAIN Mills (CCM) Roof Shielding Package

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1/28/2021

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- ER-2 Lujan Facility
- CEvNS

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- Decrease Background Events

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- General size and shape requirements

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- Design of Horizontal “flexure” members

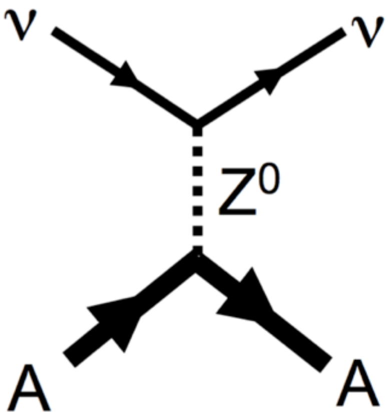
Structural Analysis

- ASCE design loads
- Sizing of welded and bolted connections

Conclusion

- Anticipated cost of structure
- Anticipated Timeline for instillation

What is the Coherent CAPTAIN Mills Experiment?



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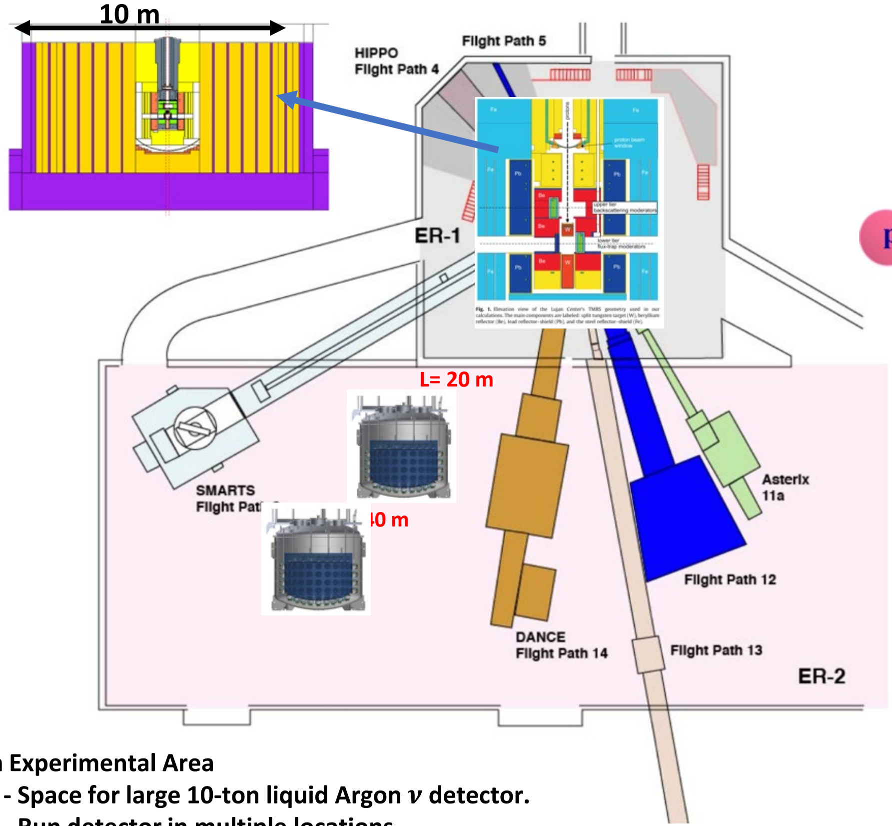
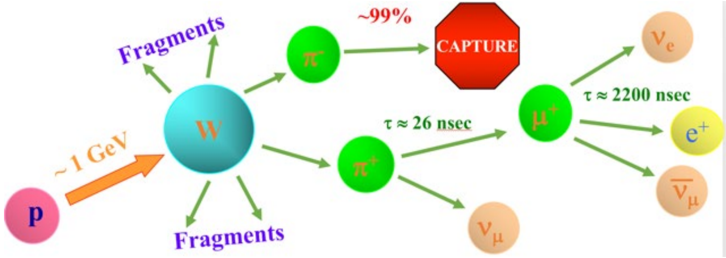
CAPTAIN = “Cryogenic Apparatus for Precision Tests of Argon Interactions with Neutrinos”

Nuclear Instruments and Methods in Physics Research A 594 (2008) 373–381
Nuclear Instruments and Methods in Physics Research A 632 (2011) 101–108

Lujan Facility at LANSCE



Intense source muon neutrinos: target MCNP simulation flux 4.74x10^5 ν/cm^2/s at 20 m



Lujan Experimental Area

- Space for large 10-ton liquid Argon ν detector.
- Run detector in multiple locations.
- Room to deploy shielding, large overhead crane, power, etc

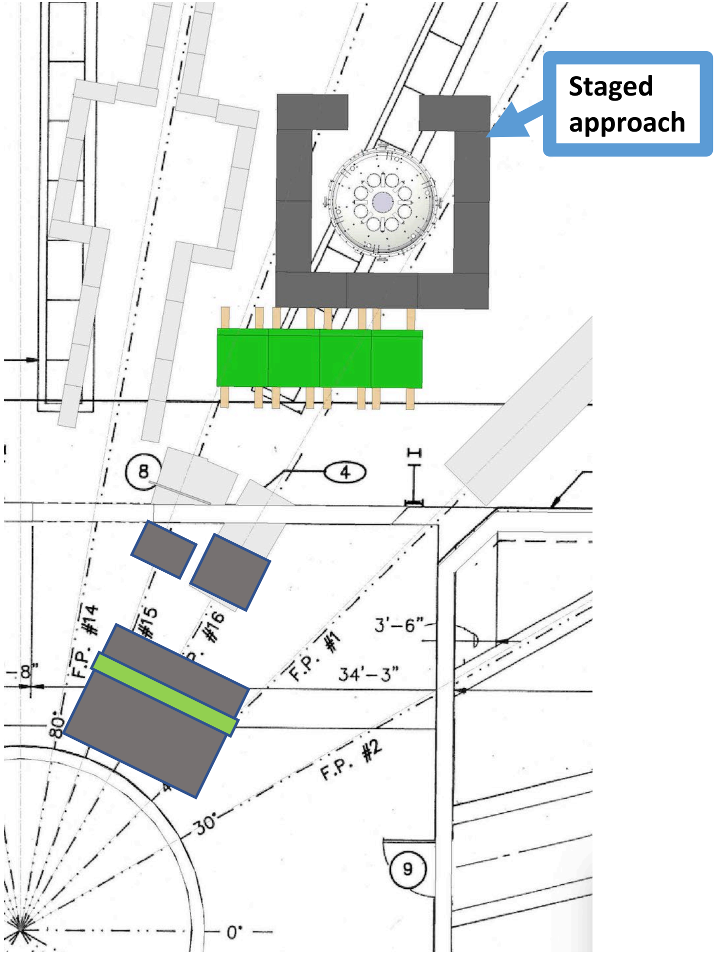
CCM120 Detector

- 120 PMT's to detect scattering events
- Number of PMT's are doubled in CCM200 detector

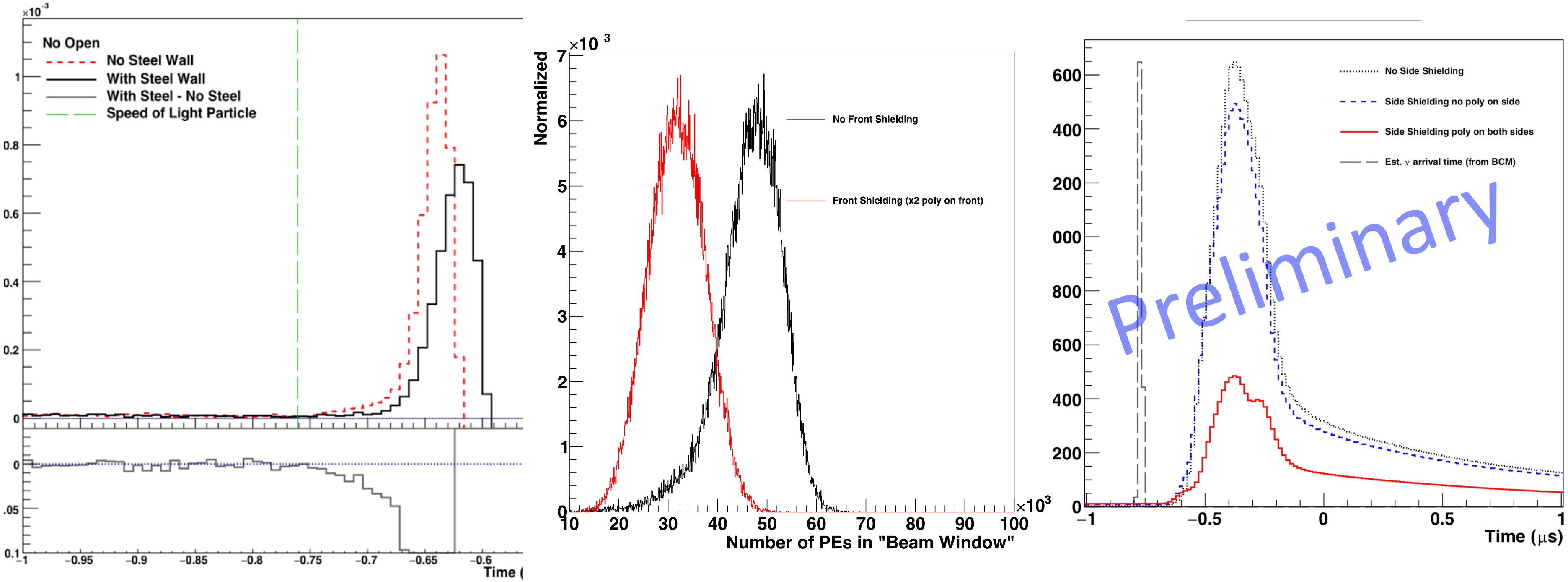
The inside of the CCM120 detector

Why is Shielding important?

- During the 2019 beam cycle we methodically added shielding and measured the activity in detector



Shielding delays beam related activity in detector



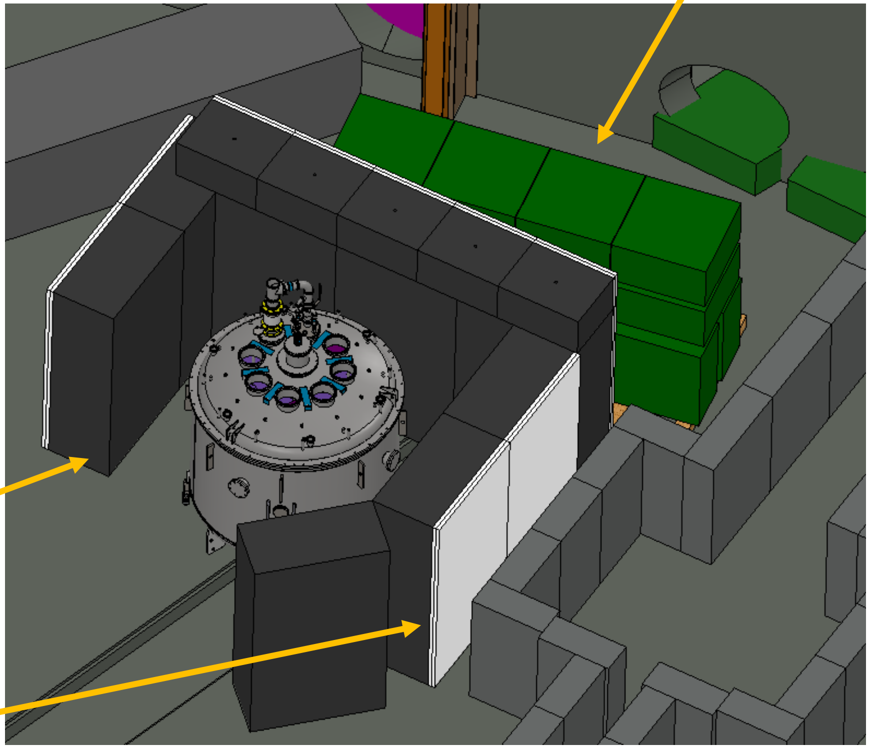
Steel shielding: decreases beam-related rate and increases delay

Front concrete: decreases bream-related energy deposition in CCM

Side shielding: decreases beam-related rate

Current Shielding Configuration

- Allows fast neutrons to interact with the detector from above
- Gamma rays produced in the concrete interact with the detector.



52” Thick Steel Block

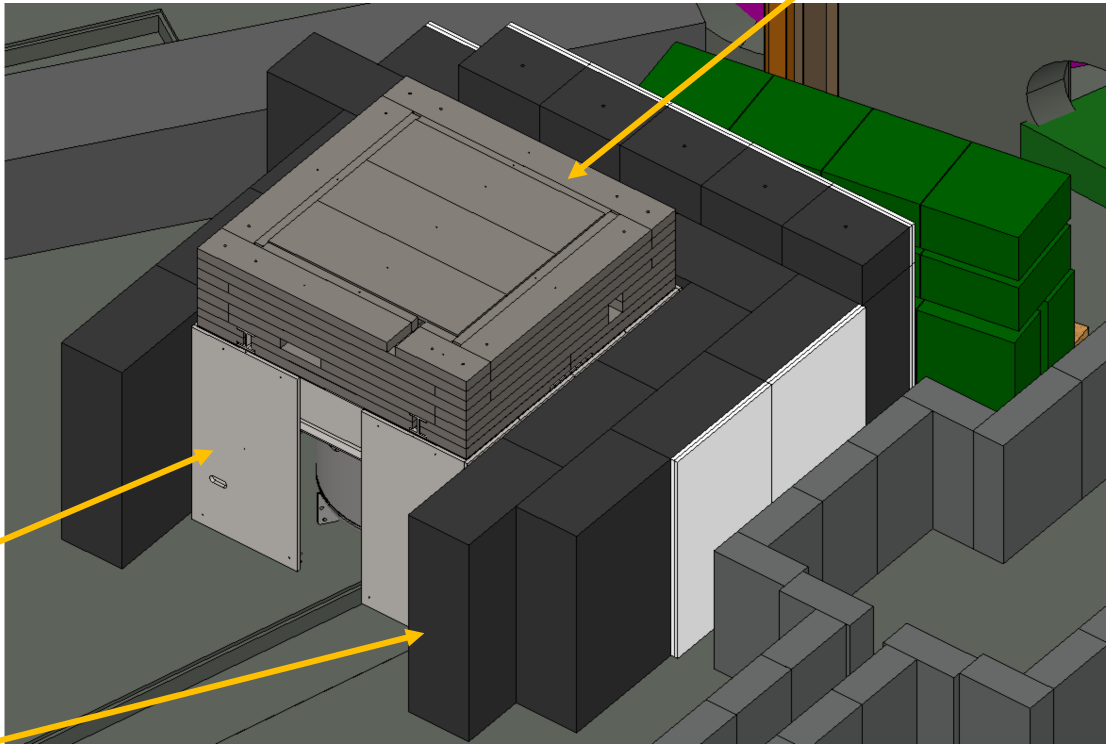
3’ Thick Concrete Blocks

2” Thick Poly Sheets

Proposed Shielding Configuration

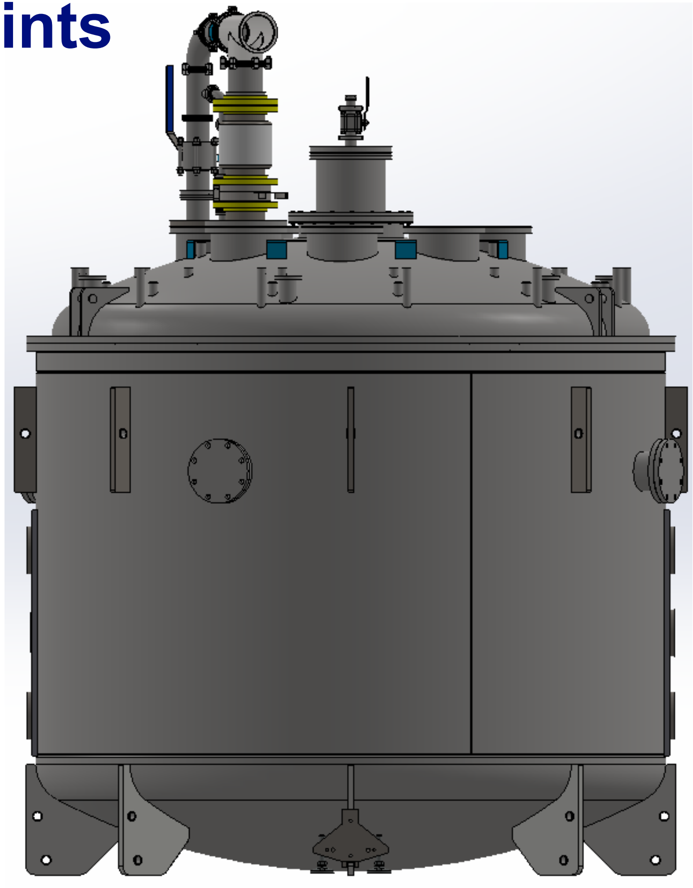
- Shields from fast neutrons that could interact with the detector from above

- Shields from gamma ray production inside the concrete



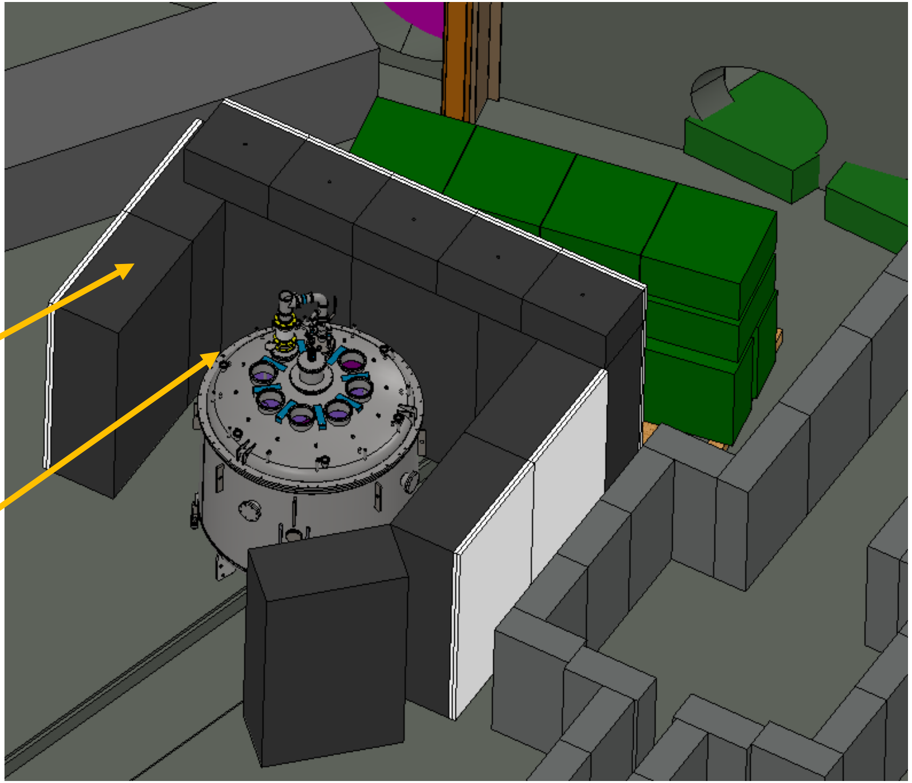
Size and Shape Design Constraints

- Detector shape and size
  - Require space directly above the detector for operations
  - Shielding should be installed as close to the detector as possible
  - Shielding should enclose the detector
  - As much steel should be added vertically without interfering with the 172” crane hook in the area



Shape of the detector

- Is shielded well on three sides with concrete and steel blocks in the area
- Need to add shielding above the detector

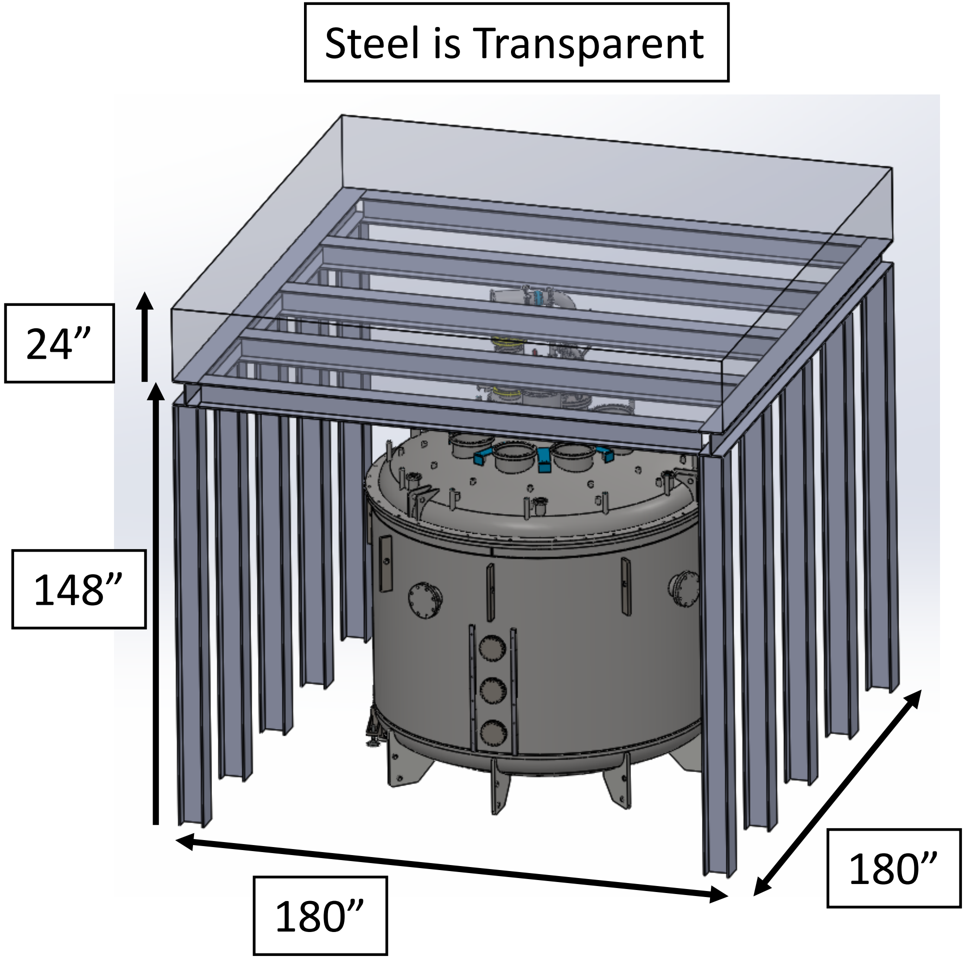


Standard Design

- Steel clears everything installed over the detector. Does not interfere with equipment on the top hat

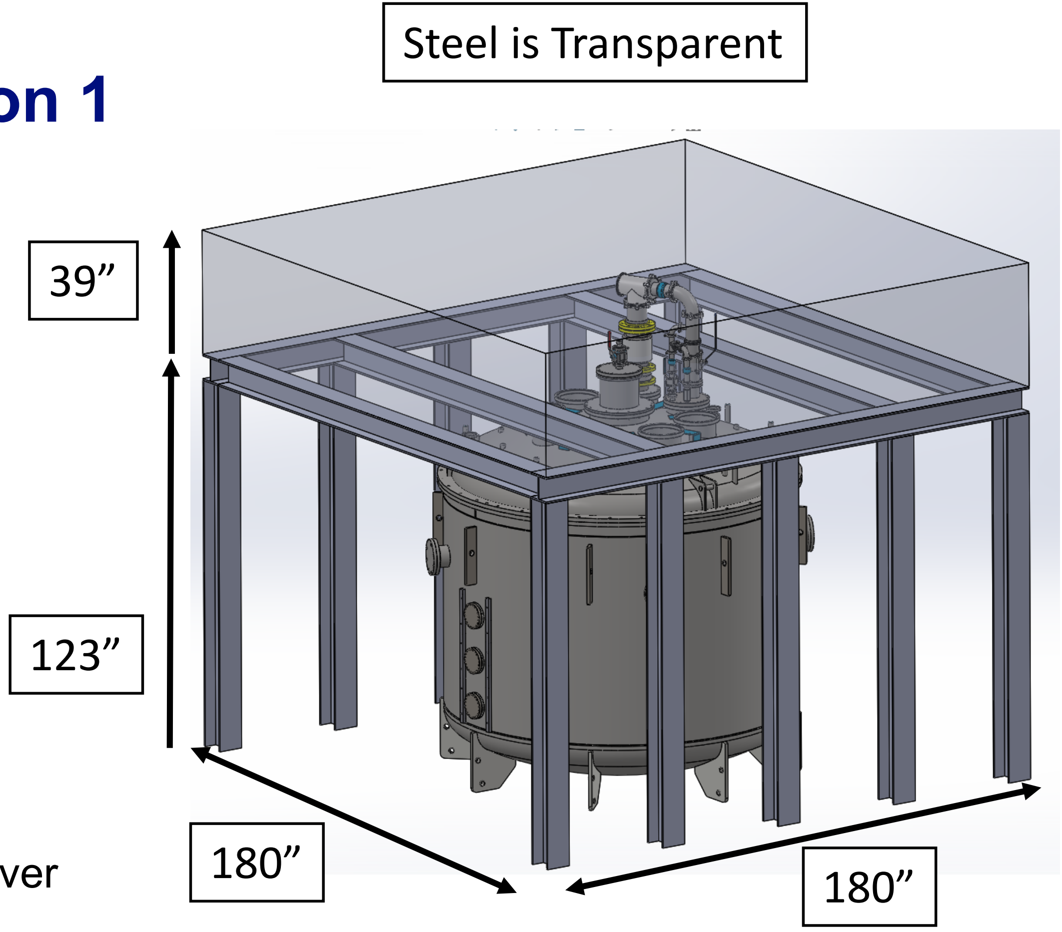
- Not ideal given the height of the detector and maximum height of shielding we can install.
  - Maximum steel shielding is 24”

- Lots of exposed area around the detector



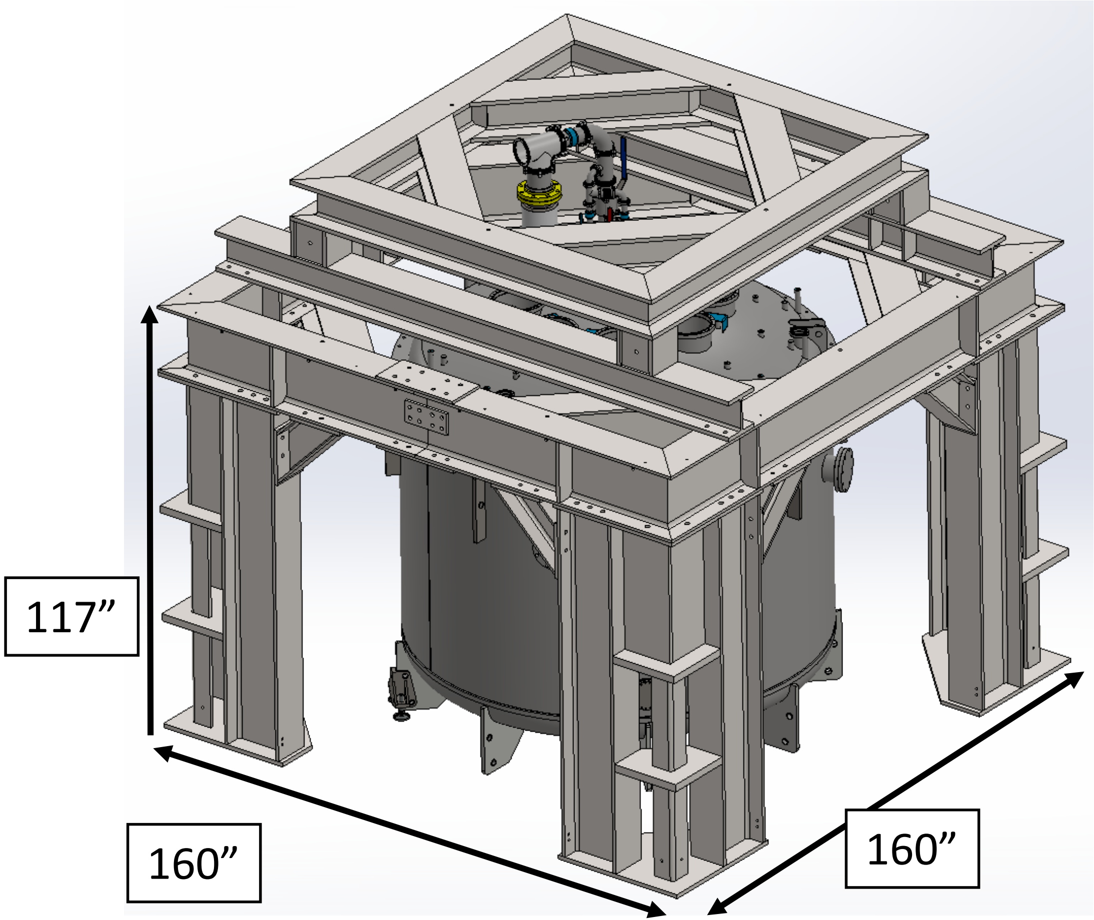
Standard Design. Revision 1

- There is interference with the equipment over the top hat
  - Requires a cavity in the shielding
- Less exposed area around the detector
- Can we optimize this design?
  - Decrease the 180”x180” footprint
  - Increase the amount of shielding over the detector (>39”)



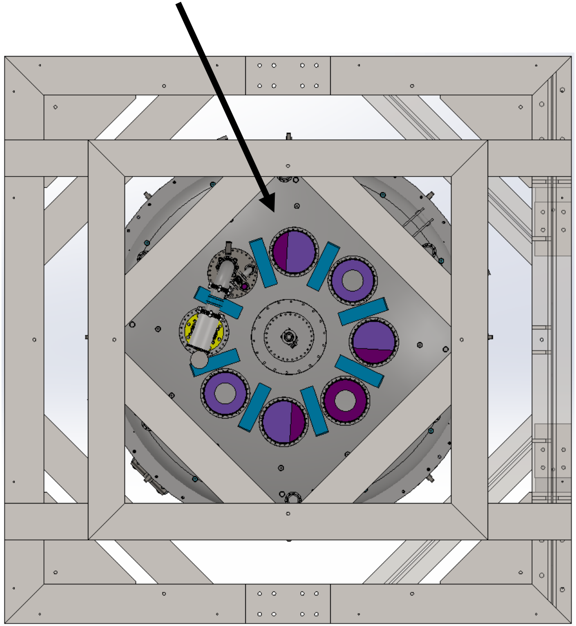
Final Design

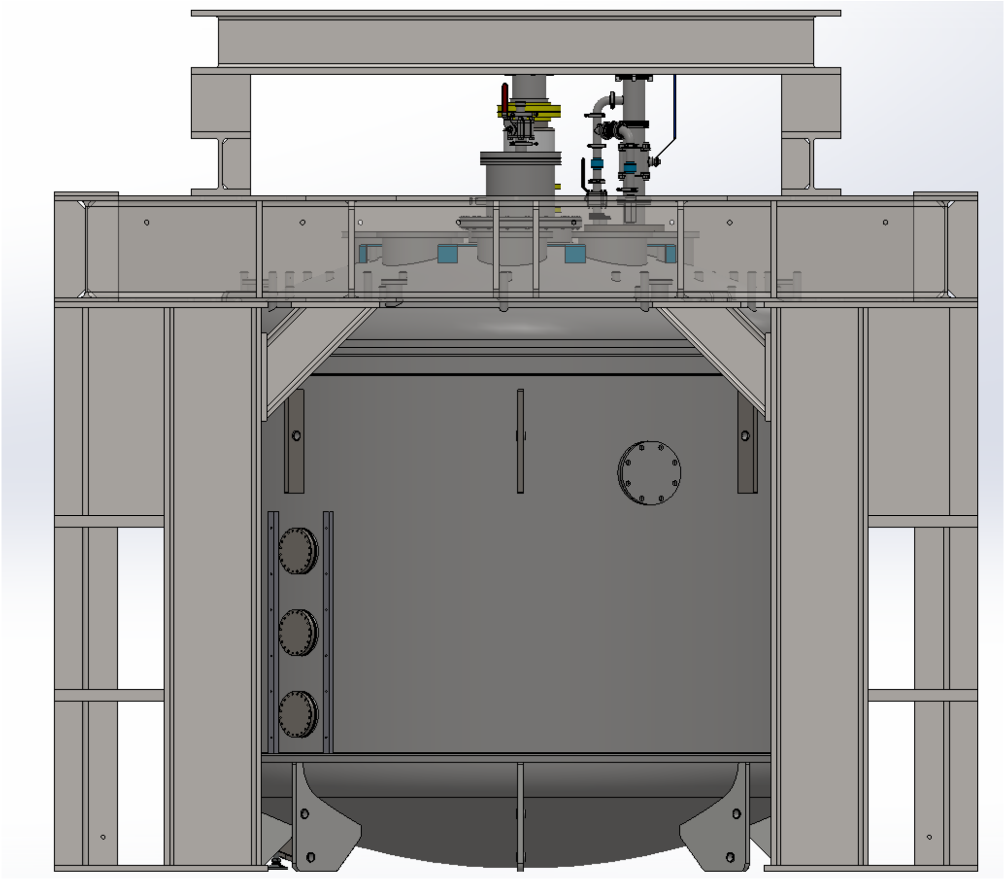
- Steel does not interfere with equipment on the top hat
- Diagonal members used to support steel not directly over the detector
- 44” of steel can be installed above the roof
- 24” installed above the cavity



Cavity Design

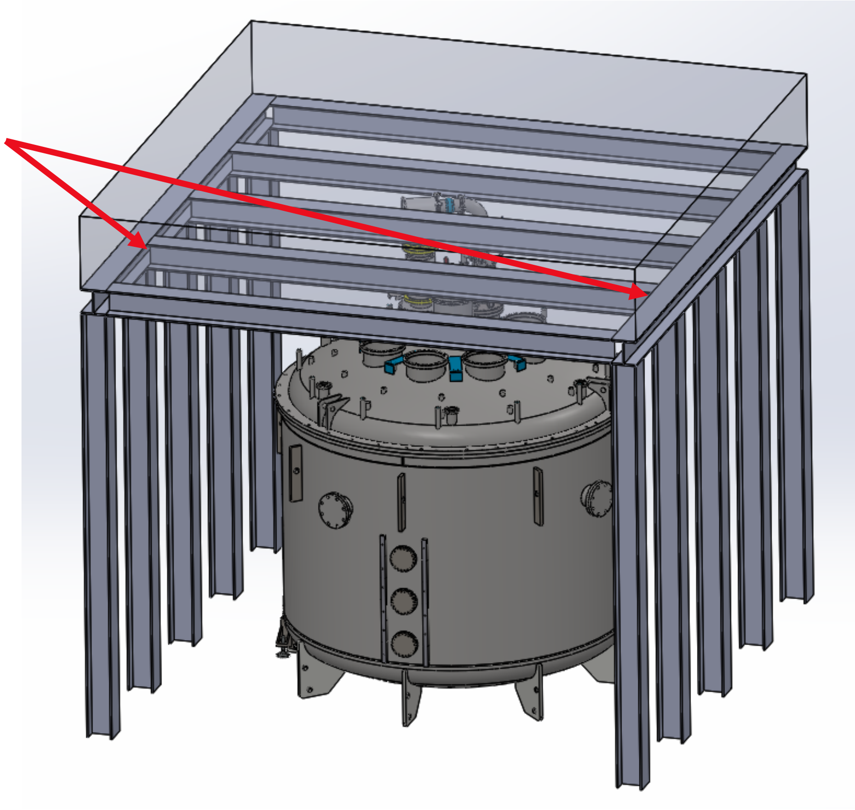
- Approximately 70”x70” space to work on top of the detector





Beam Size in Final Design

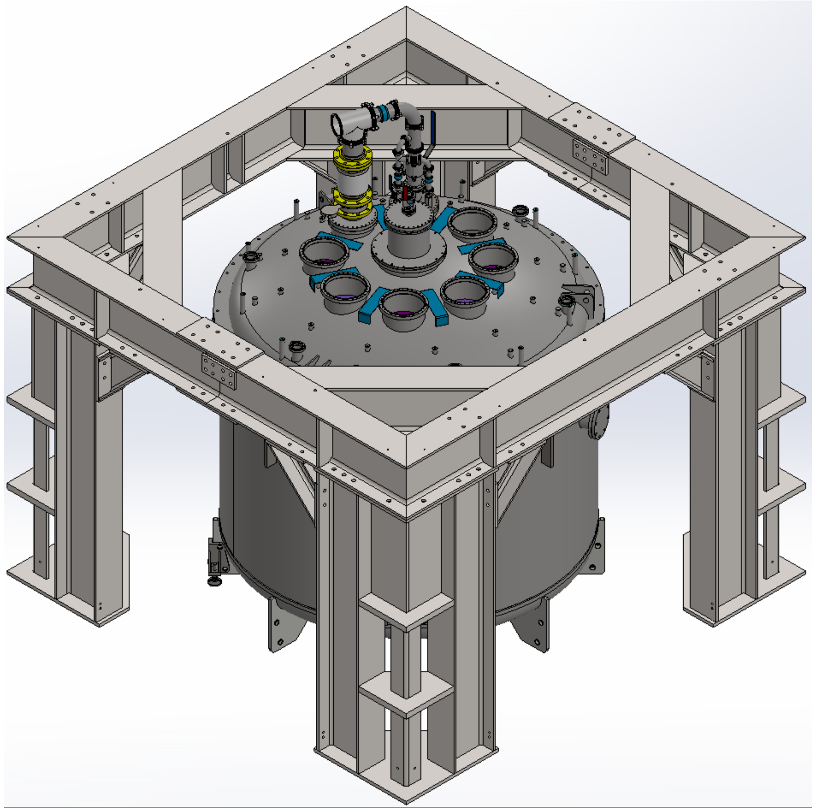
- Can calculate the maximum bending stress on the beams to the right using textbook equations.
- The density of the steel x height of steel is the pressure over the area supported by the 5 beams. (Force/Area)
- This pressure can be broken down into 5 line pressures. (Force/Length)
- Assume the 5 parallel beams are fixed at the ends
- Calculate the bending stress on the member with the largest line pressure.



Beam Size in Final Design

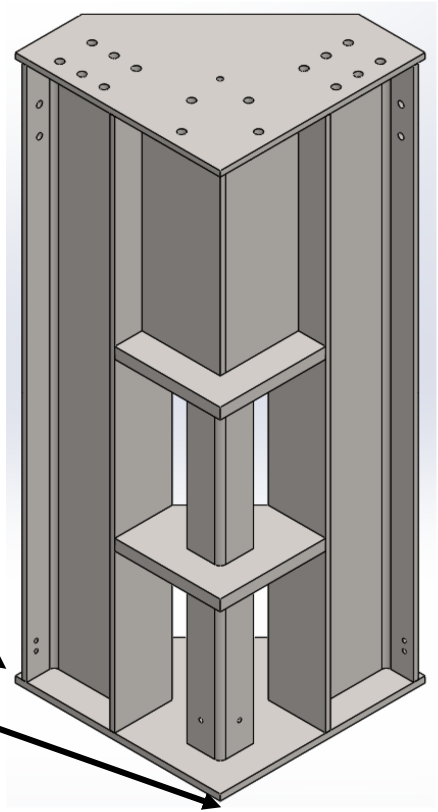
- The results give an estimate on the required beam size and elastic modulus
  - W40x167 beam
    - 5ksi bending stress
    - 600in^3 Elastic modulus
  - W18x86 beam
    - 20ksi bending stress
    - 166in^3 Elastic modulus

- Could quickly iterate and optimize the beam size comparing these results to FEA analysis.



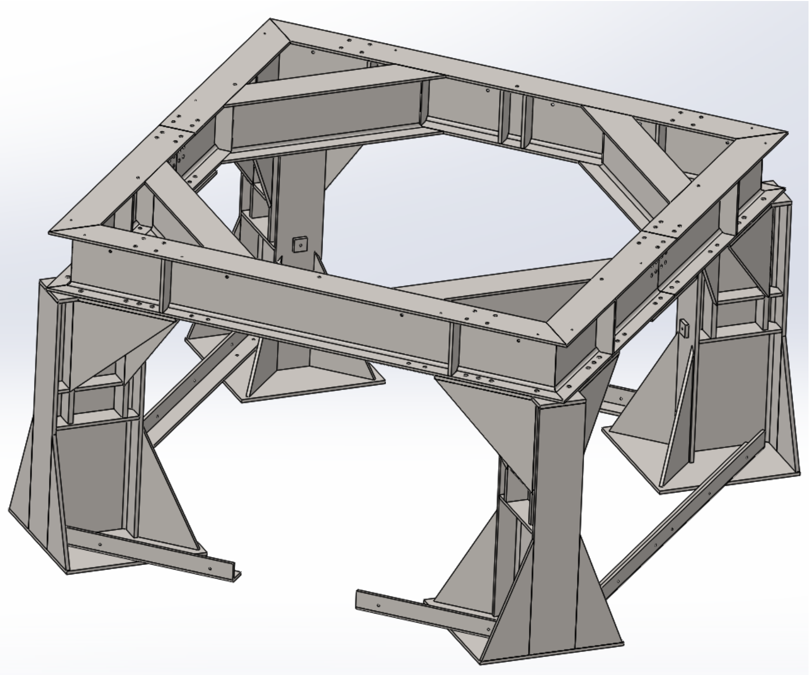
Design considerations of vertical members

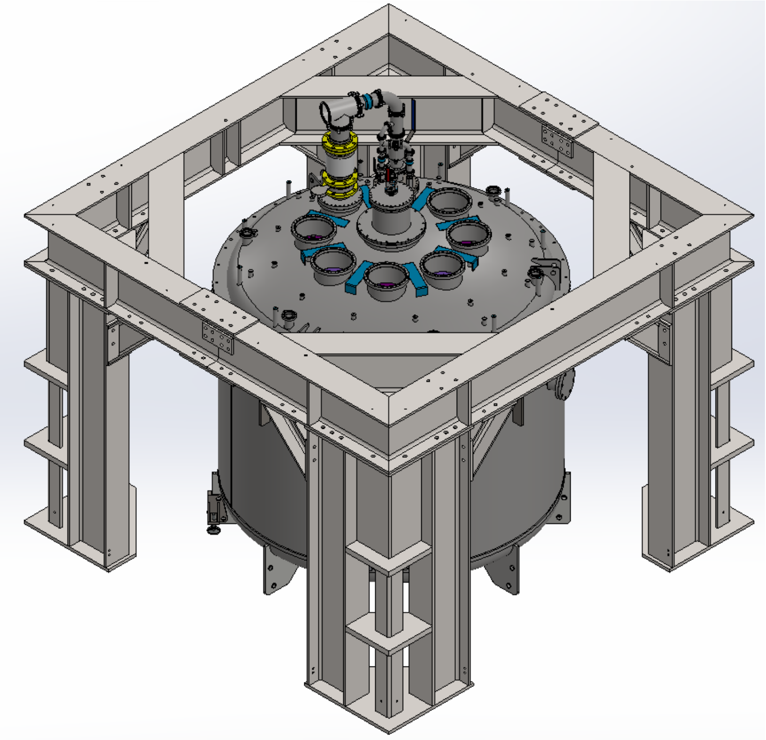
- Resist bending in two independent directions
  - One beam angled at 45degrees or two beams per leg
- The pressure applied to the floor could not be too high ~3ksi
  - Cross section must have large enough area
- Must stand erect and remain stable during construction
  - Requires foot plate
- Square in shape to allow walls to enclose detector



Resist bending in two directions

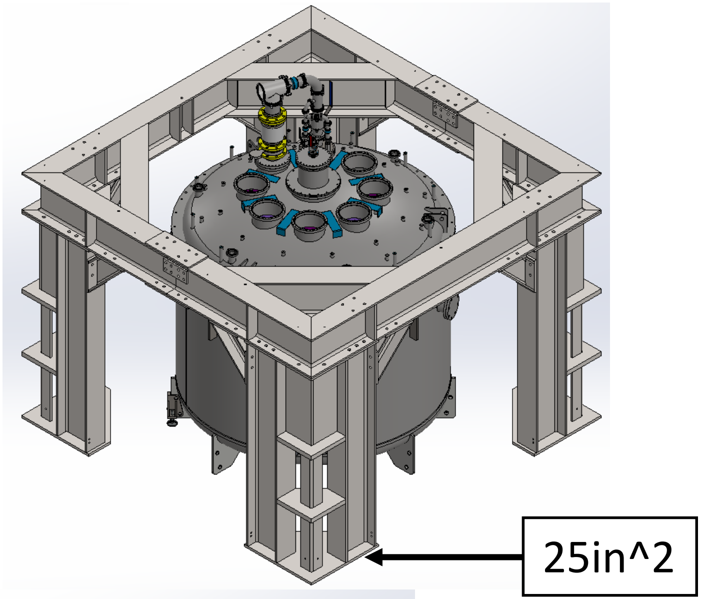
- Consider two designs to accomplish this

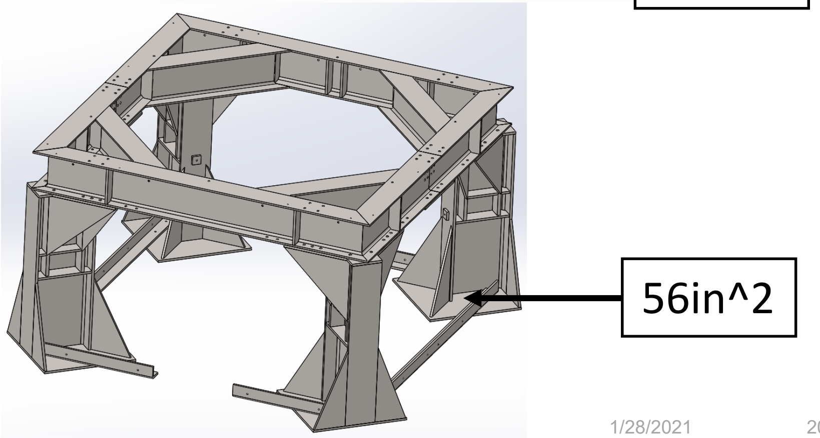




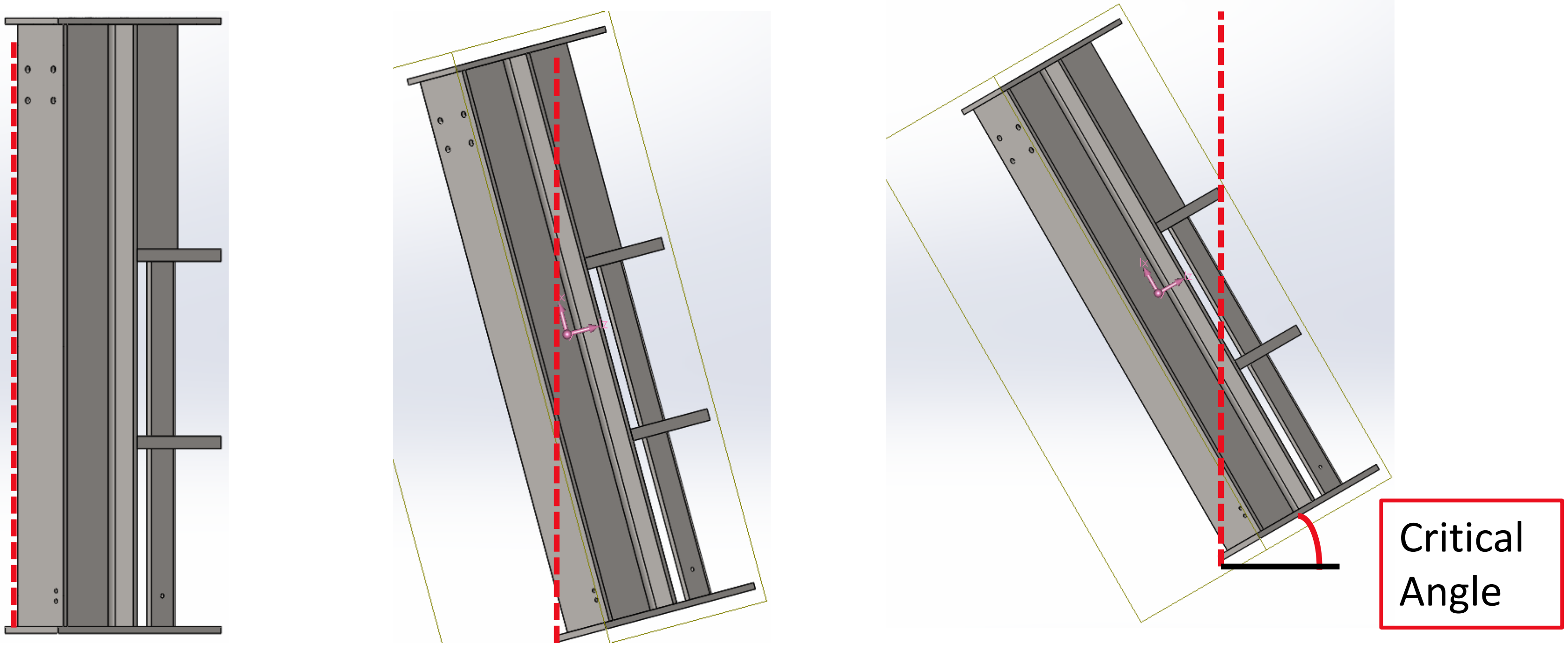
Pressure transmitted to the floor

- Approximately 150 tons to support
- Cross section required = 100in^2 = 300,000lbs/3000ksi
- Required Area for 4 legs = 25 in^2/leg
- Required Area for 8 legs = 12.5in^2/leg





Leg must stand erect with stability during construction

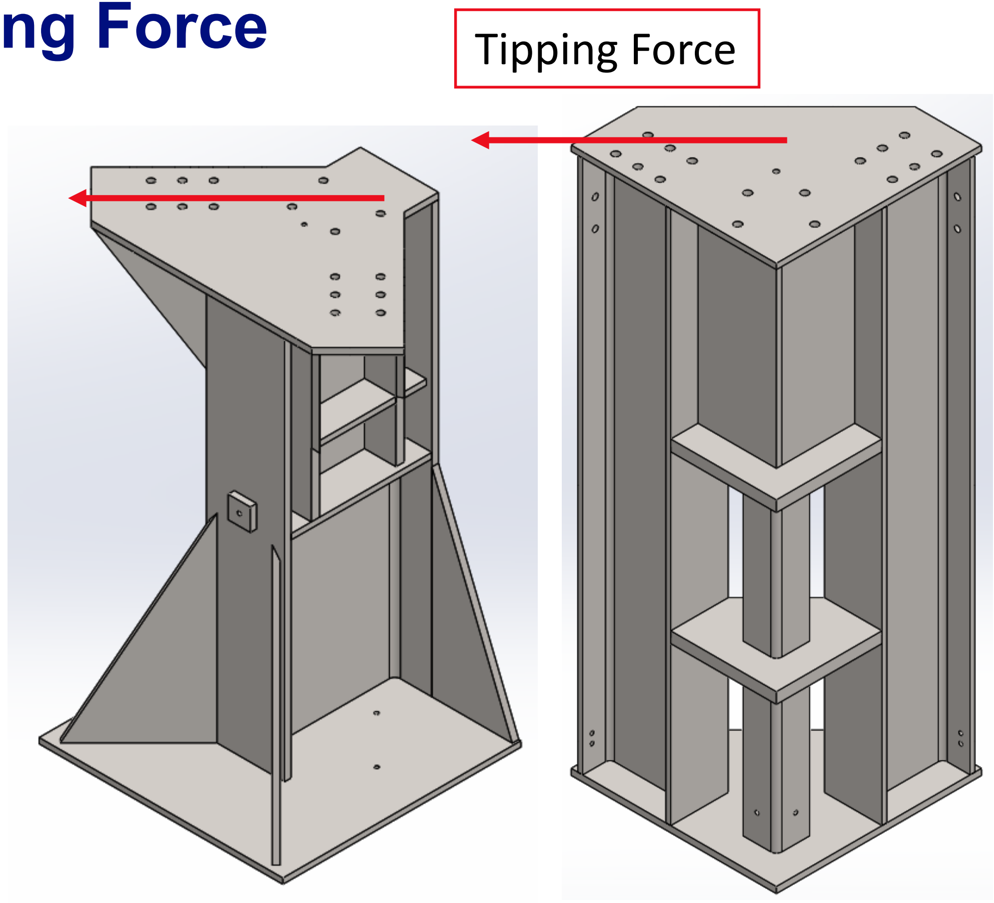


- Guiding principle is that rigid objects “fall over” when their center of mass crosses a perpendicular line from the floor.

Critical Angle and Tipping Force

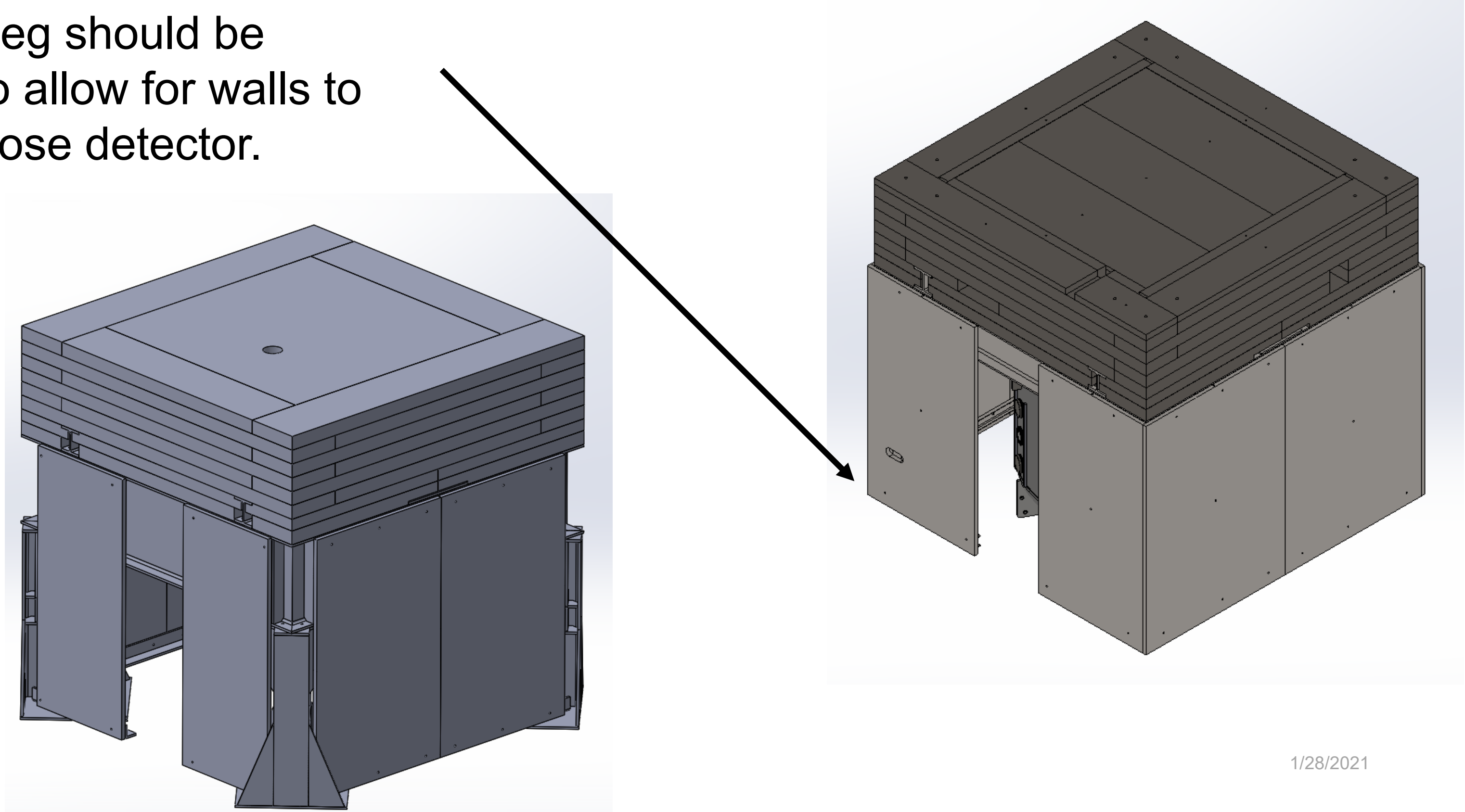
- Critical Angle for single beam design = 17°
  - Tipping Force = 586lbs

- Critical angle for dual beam design = 16°
  - Tipping Force = 406lbs

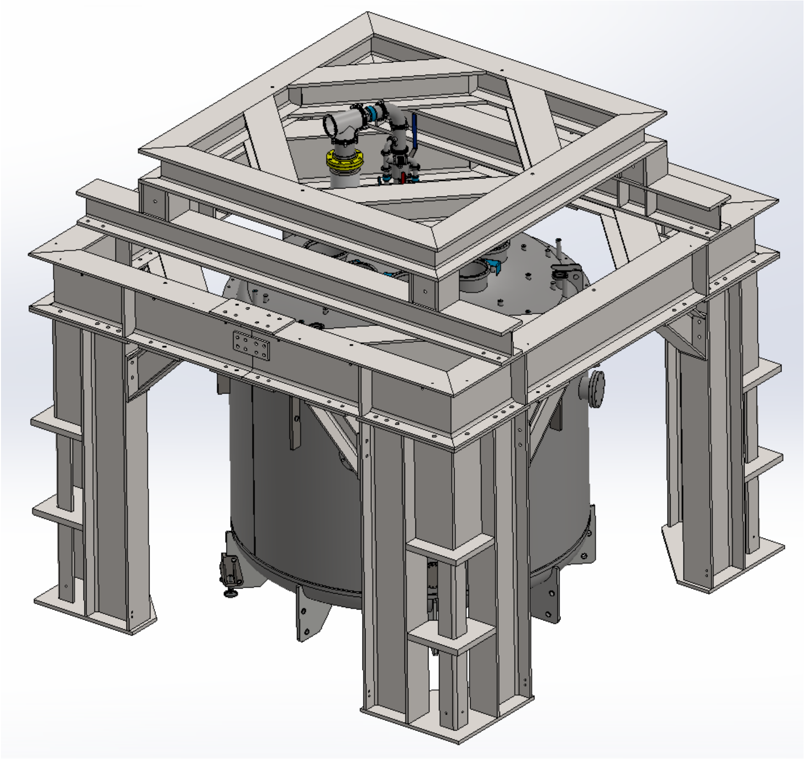


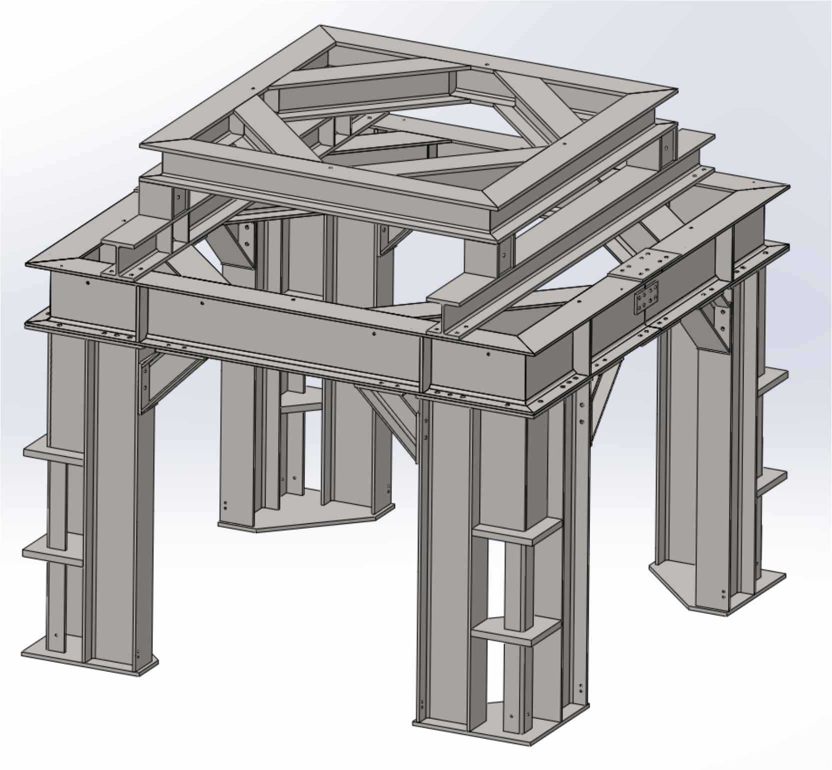
Must be square to fully enclose detector

- Edge of leg should be square to allow for walls to fully enclose detector.



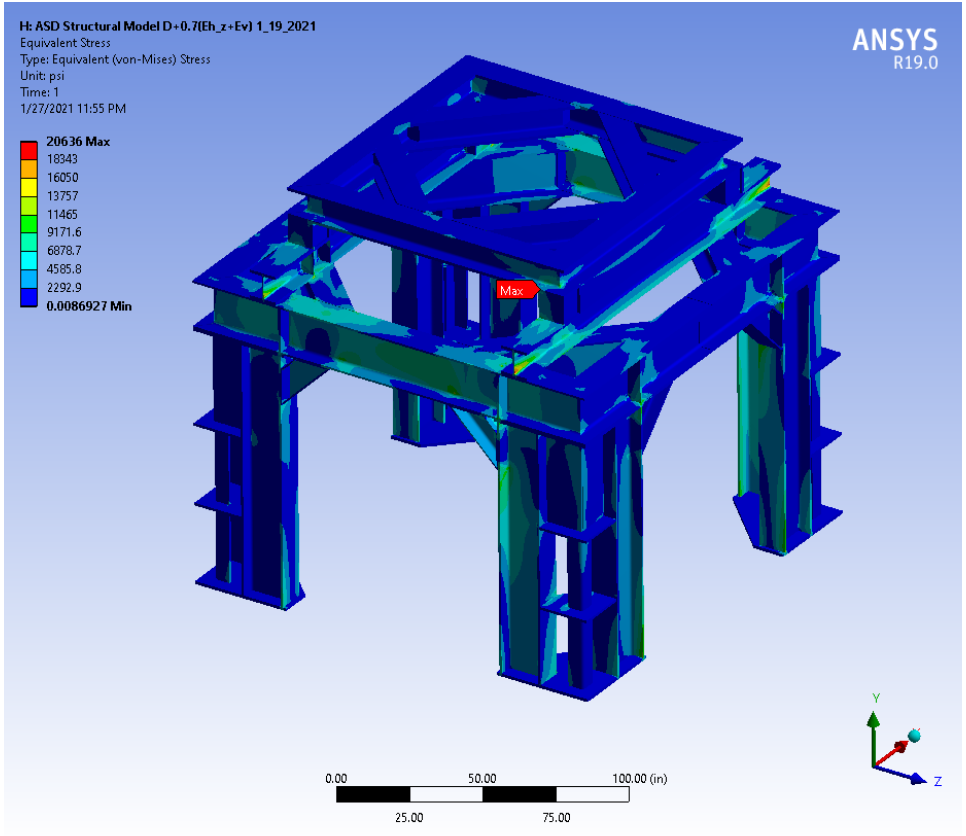
Final Design of Structure





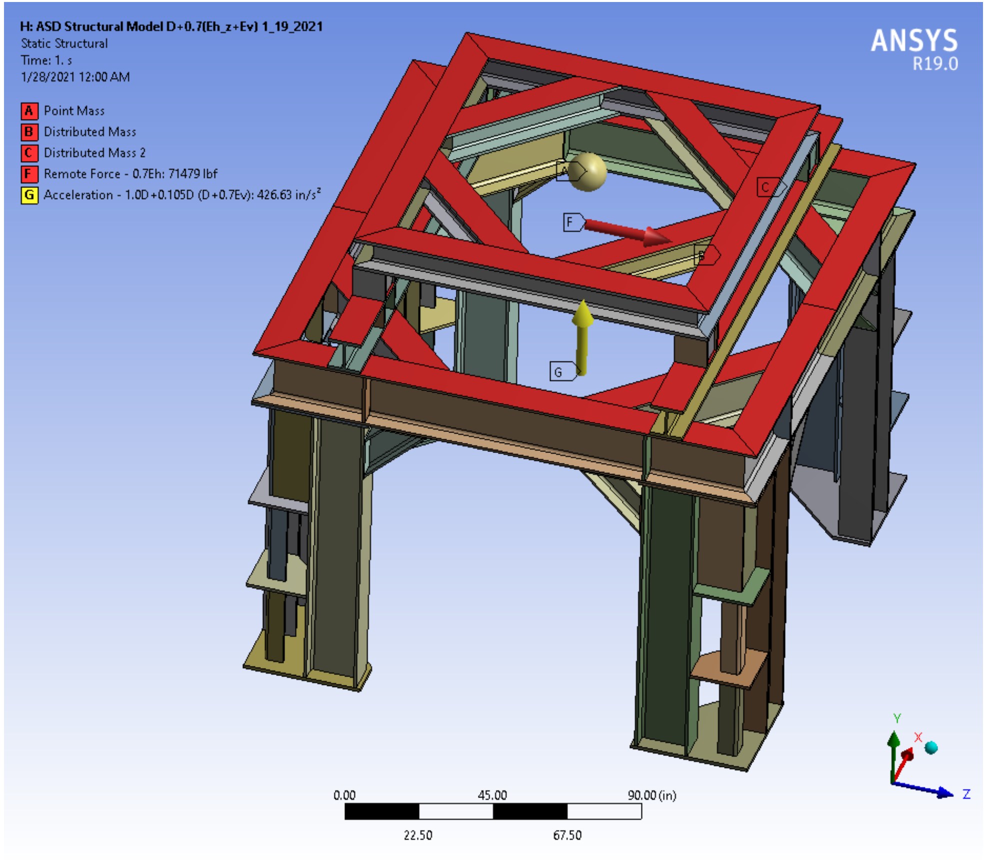
Structural Analysis

- Followed the ASCE design loads handbook



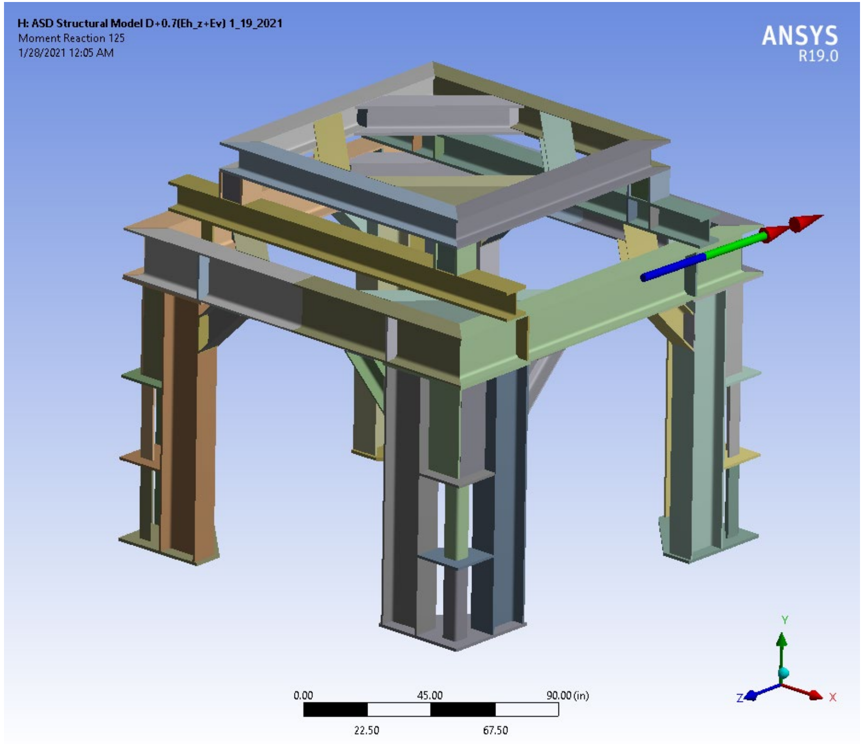
ASCE Design load 5
D + 0.7(Eh+Ev)

- Point mass and distributed mass were used to model the steel installed on the structure.
- Acceleration in the vertical direction was used to model the dead load and vertical seismic force
  - Ev = 43kip
- A horizontal seismic force was applied to the face of the two weldments
  - Eh = 102kip
- Factor of Safety of 1.5



Sizing of 22 unique welded and bolted connections

- Force and moment at each contact can be retrieved using ANSYS
- There are 300 total connections in the model. They can be grouped into 22 unique connections
- Welds and bolts can be sized using textbook formulae and appropriate safety factors (2).



What is next?

- The structure is at the shops being quoted
  - An early budgetary estimate puts the full structure at over $500K
- Assemble the structure this summer
- This shielding package should reduce background and improve our sensitivity leading to a better measurement.